



# Ultrasound–CT fusion compared with MR–CT fusion for postimplant dosimetry in permanent prostate brachytherapy

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## ABSTRACT

**PURPOSE:** Postplan evaluation is essential for quality assurance in prostate brachytherapy. MRI has demonstrated greater interobserver consistency in prostate contouring compared with CT. Although a valuable tool in postimplant assessment, MRI is costly and not always available. Our purpose is to compare dosimetry obtained using fusion of postimplant CT with preimplant transrectal ultrasound (TRUS) vs. CT–MR fusion.

**METHODS AND MATERIALS:** Twenty patients receiving permanent <sup>125</sup>I seed prostate brachytherapy underwent preimplant TRUS with urethrography, 1-month CT with a Foley catheter, and 1-month MRI. No patient received androgen deprivation therapy or external beam radiotherapy. The prescription dose of <sup>125</sup>I implant monotherapy was 144 Gy. The preimplant TRUS and postimplant CT images were fused based on urethral position, and the CT–TRUS images were subsequently fused to the MRI using a seed-to-seed match. Dosimetric parameters for the ultrasound- and MR-derived prostate were compared.

**RESULTS:** The mean absolute difference between dosimetry from MRI or CT–TRUS fusion for  $D_{90}$  was 3.2% and in  $V_{100}$  was 1.2%. Only 1 patient had a difference in MR- and ultrasound-derived  $D_{90}$  of more than 10% (11.4%) and only 1 had a difference in  $V_{100}$  of more than 5%.

**CONCLUSIONS:** Fusion of preimplant TRUS with 1-month postimplant CT appears to lead to acceptable agreement with MR-based dosimetric parameters in postplan evaluation. TRUS-based volumes may be a reasonable alternative to MRI in settings where MRI is not available. © 2013 American Brachytherapy Society. Published by Elsevier Inc. All rights reserved.

## Keywords:

Prostate neoplasms; Interstitial brachytherapy; Dosimetry; Quality assurance; Image fusion

## Introduction

Postimplant evaluation is essential for quality assurance in permanent seed prostate brachytherapy (BT). CT imaging alone is most commonly used in implant evaluation, although the prostate edge is difficult to define, particularly when considering the artifact produced by the implanted seeds. MRI is associated with greater interobserver consistency and accuracy in prostate delineation

compared with CT, which tends to overestimate the prostate volume. This has been demonstrated both in patients receiving external beam radiotherapy (1–6) and in those undergoing permanent seed BT (7–9). Even small changes in contouring can be associated with large apparent dosimetric differences (10) highlighting the need for accurate imaging in postimplant assessment.

CT–MR fusion has become a valuable tool in postimplant assessment and improves accuracy of postimplant dosimetry compared with approaches that use CT imaging only (11–13). Because MRI is limited by cost and availability, exploration of other imaging modalities may be helpful. Information from the preoperative transrectal ultrasound (TRUS), such as prostate length, shape, and volume, can be incorporated into postimplant assessment and may be an improvement over the use of CT imaging alone. A recent study by Smith *et al.* (8) in patients undergoing TRUS, CT, and MRI 30 days after BT showed less contouring variability

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Conflict of Interest: None of the authors declares a conflict of interest concerning the material presented in this manuscript.

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and closer correspondence between TRUS and MRI than that between either of these modalities and CT. This suggests that TRUS may be a viable and convenient alternative to MRI in settings where MRI is not available and should improve on the accuracy of CT-based contouring. The purpose of this study is to compare dosimetry obtained using fusion of the preimplant TRUS and Day 30 postimplant CT (CT–TRUS fusion) to fusion of the Day 30 CT to MRI (CT–MR fusion).

## Methods and materials

Twenty men undergoing permanent  $^{125}\text{I}$  seed BT at the British Columbia Cancer Agency Center for the Southern Interior between January and June 2011 were included in this study. No patients received androgen deprivation therapy (ADT) or external beam radiotherapy. The prescription dose of the  $^{125}\text{I}$  BT implant was 144 Gy. Loose seeds were used for all 20 patients. Patients were eligible if urethrography was performed at the time of preoperative TRUS and if catheterization was performed with CT imaging 30 days postimplant. All patients at our institution undergo TRUS planning before implantation, generating axial images every 5 mm, including one slice above and below the prostate gland. Urethrography with aerated gel is performed for planning purposes to permit limitation of the urethral dose to 125% of the prescribed dose in the preplan. CT and MRI are generally performed 30 days postimplant, using the following MR sequence: fast spin-echo T2-weighted (1.5 T), repetition time = 4500 ms, echo time = 90 ms, echo train length = 10, field of view =  $20 \times 20$  cm, 3 mm slice thickness, 0 mm gap, and bandwidth = 80 Hz/pixel. The CT and MR images are manually fused for dosimetric assessment, using the seed positions on CT and signal voids on MR as fiducial markers. Catheterization for urethral identification at the time of the Day 30 CT is performed to facilitate calculation of urethral dose.

For this study, the TRUS and CT images were fused manually based on the urethral position as determined by TRUS urethrography and the position of the Foley catheter on 1-month CT. Fusion was performed by overlying the sagittal images in the plane of the urethra to superimpose the urethral curvature to bring the base and apex into alignment (Fig. 1). The prostate was contoured on the planning TRUS images before implantation. Fusion was performed by one of two radiation oncologists (JMC or DB). The prostate was then contoured on the MR images (JMC or DB), and the fused CT–TRUS images were subsequently fused to the MRI matching MR seed voids to the seeds visible on CT. Dosimetry was then calculated based on the MRI prostate contours and the TRUS prostate contours (Fig. 2). The following dosimetric parameters for the TRUS- and MR-derived prostate were collected and compared: prostate volume,  $V_{100}$ ,  $D_{90}$ ,  $V_{150}$ , and  $V_{200}$ . Values are reported as medians, means, interquartile ranges, and standard deviations using SPSS (SPSS Inc., Chicago, IL) software version 17.0 for statistical analysis, with the  $p$ -value of 0.05 or less being considered statistically significant.

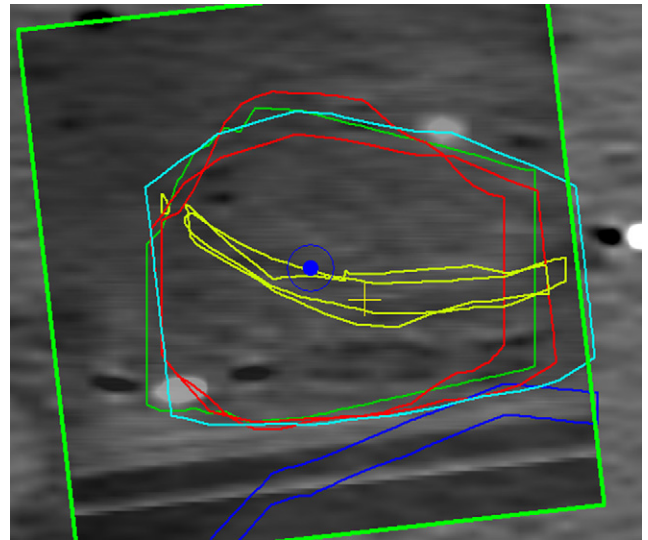


Fig. 1. Overlaying the sagittal images in the plane of the urethra superimposes the urethral curvature and brings the base and apex into alignment.

## Results

Dosimetric parameters were calculated using the contours from the CT–TRUS fusion and from the MR–CT fusion and are shown in Table 1.

There were no significant differences in  $D_{90}$ ,  $V_{100}$ ,  $V_{150}$ , and  $V_{200}$  ( $p < 0.001$ ) when comparing dosimetric parameters obtained using MRI and CT–TRUS fusion (Table 2). Despite this, there was a small group of patients for whom agreement in the measured parameters was not as good, as shown in Table 3.

Five patients had differences in MR- and ultrasound (US)-derived  $D_{90}$  of between 5% and 10%, and 1 patient had a difference of 11.4%. Such differences were much less common in  $V_{100}$ ,  $V_{150}$ , and  $V_{200}$ , with 19 of 20 patients having a difference in  $V_{100}$  of less than 5%. There were no implants in this group in which the  $D_{90}$  was less than 110% of the prescription dose (as determined using either MR- or TRUS-based imaging). Although 11 of 20 patients had differences in prostate volume between MR and TRUS of more than 10%, the actual magnitude of the difference was small with a mean absolute difference as calculated between MR and US of only 3.0 cc (maximum, 7.5 cc). The relation of MR and TRUS volume is shown in Fig. 3.

## Discussion

This study suggests that fusion of CT and TRUS may be a reasonable alternative to MR-based dosimetry in patients where MRI is not available. The major advantage of this approach is that TRUS images are readily available. Incorporating preplan TRUS into postoperative evaluation does not require the use of additional resources beyond those needed for planning, and this approach does not impose any inconvenience to the patient. In our experience, CT

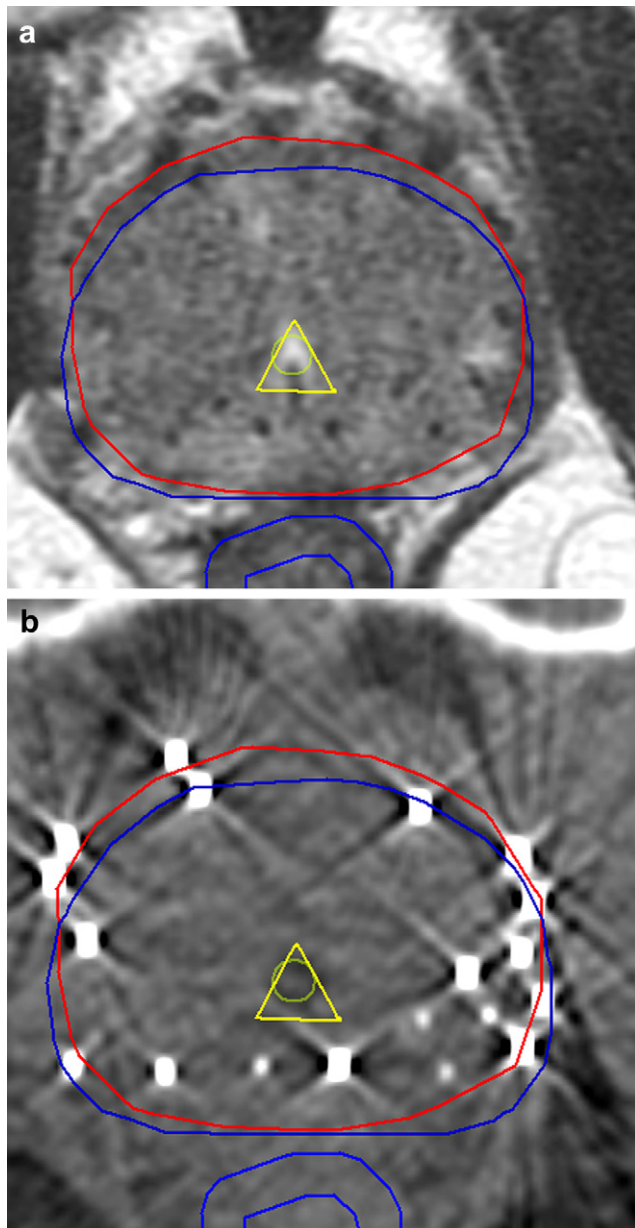


Fig. 2. Transverse midgland images showing prostate contours from transrectal ultrasound (TRUS, blue) and MRI (red) superimposed on (a) MR and (b) CT images. Urethra is a circle on CT and triangle on TRUS. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

and TRUS images can be fused in about 5 min, and the fusion could be performed by a physician, physicist, or a dosimetrist.

The utility of CT–TRUS fusion in postimplant quality assurance may be affected by a number of patient-related factors. First, the presence of the TRUS probe may deform the prostate in some patients. The most commonly observed change in shape was a result of posterior pressure of the US probe to raise the prostate to Row 1 of the template grid. Pulling posteriorly on the rectal wall causes the prostate to move anteriorly on the grid, away from the rectal wall. This results

Table 1

Median volume and dosimetric parameters as calculated using CT–TRUS fusion and CT–MRI fusion

Median value (IQ range)	CT–TRUS	CT–MRI
Volume (cc)	32.8 (25.8–42.6)	31.1 (25.8–37.6)
$D_{90}$ (%)	120.0 (117.4–132.2)	122.8 (115.0–132.4)
$V_{100}$ (%)	97.8 (95.4–98.9)	97.8 (94.9–98.8)
$V_{150}$ (%)	71.5 (64.7–75.6)	72.6 (62.7–77.5)
$V_{200}$ (%)	37.2 (28.9–41.2)	36.0 (26.6–42.4)

TRUS = transrectal ultrasound; IQ = interquartile.

in a very flat posterior aspect of the gland. Without the probe in place, the prostate reverts to a more rounded shape with the posterior aspect closer to the rectal wall (Fig. 4). The use of a large caliber or stiff catheter at the time of CT may change the urethral curvature and make fusion of CT and TRUS more difficult (Fig. 5), but this effect can be minimized by the use of the smallest possible catheter, generally a 14 French. Either situation will inherently affect the relevance of US-derived contours to the unperturbed state of the prostate. The identification of either situation could be used to trigger MRI in settings where MR is available but not routinely performed. Despite these limitations, the fused TRUS contours remained very helpful, especially at the base of the prostate as illustrated in Fig. 6.

Edema is another potential source of perioperative change in prostatic shape or volume. Taussky *et al.* (14) evaluated the time course of edema development and resolution after permanent seed BT. The median prostate volume was 5% larger 30 days after implantation than the baseline, causing a small but statistically significant effect on the prostatic  $D_{90}$ . Crook *et al.* (15) have demonstrated that a small (12%) subset of patients has a significant amount of residual prostatic edema 30 days after implantation. Although with more experience the same group found 1-month edema based on MRI to be 1%, the improvement presumably being because of more accurate needle placement and fewer needle reinsertions at the time of implant (16). The mean difference in prostate volume based on MRI vs. TRUS was 3 cc, and this may reflect persistent post-implant edema. When edema is suspected based on CT imaging, TRUS-based dosimetry may be inadequate and MRI should be arranged to optimize implant evaluation.

Table 2

Mean differences in dosimetric parameters as determined with CT–TRUS fusion vs. CT–MRI fusion

Dosimetric parameters	Mean difference (% $\pm$ SD)	Mean absolute difference (% $\pm$ SD)
Volume	$-4.9 \pm 10.6$	$9.4 \pm 6.6$
$D_{90}$	$-0.3 \pm 4.4$	$3.2 \pm 2.9$
$V_{100}$	$-0.3 \pm 1.9$	$1.2 \pm 1.6$
$V_{150}$	$0.0 \pm 2.7$	$2.1 \pm 1.6$
$V_{200}$	$0.1 \pm 1.9$	$1.5 \pm 1.2$

TRUS = transrectal ultrasound; SD = standard deviation.

Negative values indicate that larger values were calculated using CT–TRUS imaging.



Table 3

Number of patients ( $n = 20$ ) with differences in CT–TRUS and MR-derived dosimetric parameters greater than 5% or 10%

Dosimetric parameters	# With differences >5%	# With differences >10%
Volume	13	11
$D_{90}$	5	1
$V_{100}$	1	0
$V_{150}$	1	0
$V_{200}$	1	0

TRUS = transrectal ultrasound.

The use of ADT is another factor that could lead to prostate volume change over time from preplanning to implant and subsequent postimplant evaluation, especially if there has been a delay from planning TRUS to implantation, or if ADT has not been administered for long enough to achieve a stable prostate volume before BT. This study did not include patients who received ADT. If an obvious difference in prostate volume is noticed at the time of implant or at the time of postimplant CT imaging, then it would be reasonable to arrange for MRI if this is not routinely done.

The total volume of the implanted seeds is small (average 100 seeds per case  $\times$  volume per seed =  $\sim 0.35$  cc). This would not be expected to have a major effect on dosimetry and is certainly within the range of interobserver contouring variation.

Postoperative TRUS imaging could also potentially be incorporated into postimplant evaluation, although its utility is limited by the presence of the implanted seeds, which interfere with edge detection. Furthermore, this procedure may be quite uncomfortable for the patient at 1-month postimplant and as such has not been used at our center.

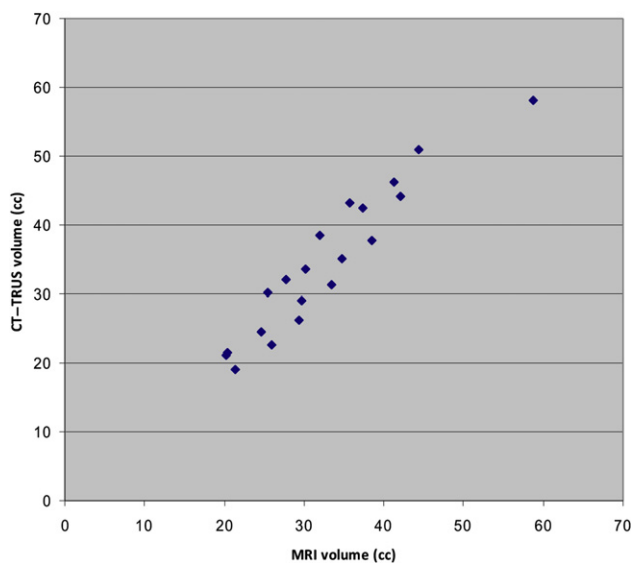


Fig. 3. Scatter plot of prostate volume as measured on preimplant TRUS vs. 1-month MRI. TRUS = transrectal ultrasound.

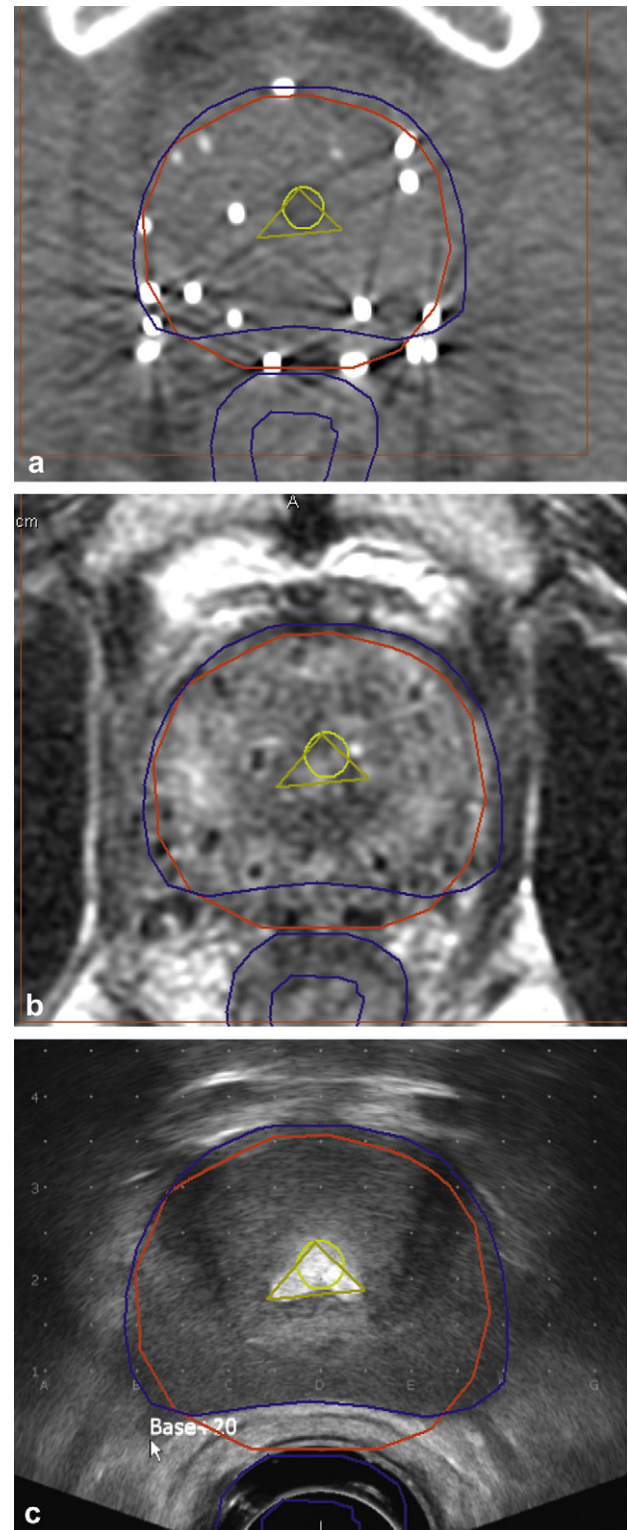


Fig. 4. Transverse midland images showing prostate contours from transrectal ultrasound (TRUS, blue) and MRI (red). Posterior pressure on the TRUS probe has moved the prostate anteriorly and flattened the posterior edge. Although the ultrasound and MR contours are nicely superimposed laterally and anteriorly, the presence of seeds clearly seen on CT “posterior” to the TRUS contour is an indication that the TRUS contour is not reliable posteriorly in this instance. (a) CT image, (b) MR image, and (c) TRUS image. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

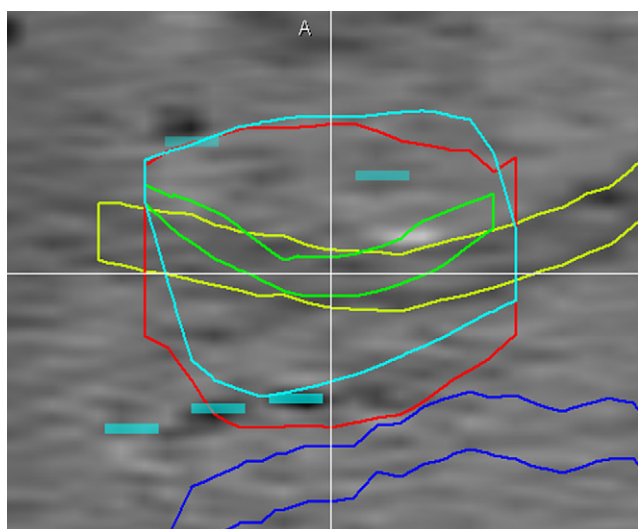


Fig. 5. Example of catheter changing urethral curvature slightly.

In our experience, CT–MR and CT–TRUS fusion is not time consuming and can be quickly learned by practitioners who are experienced in TRUS-based BT planning. It is worthwhile to note some limitations in this study. The contouring was performed by two observers, both experienced in MR–CT fusion and MR prostate anatomy. In the community, there may be variation in contouring skills and accuracy of fusion that have not been reflected in this study. In centers choosing to incorporate preoperative TRUS imaging in postimplant evaluation, review of fusion and contouring by multiple observers should be considered. Furthermore, implant quality in this cohort was generally excellent, with no implants having a  $D_{90}$  of less than 110%. There could potentially be larger differences in US- and MR-based dosimetry in less adequate implants with a higher dose gradient along the prostatic periphery.

This study did not directly compare TRUS-based with CT-based dosimetry. Contouring was performed by observers experienced in MR-based contouring, and given that the knowledge of MR-based anatomy can be used to improve CT-based contouring (17, 18), we did not believe we could provide an accurate evaluation of purely CT-based dosimetry. Such a comparison can only be made using observers who do not have experience with contouring the prostate on MRI. A recent study at our institution noted disparities in dosimetric parameters when using CT imaging alone vs. CT–MR fusion (11). We feel that TRUS-based dosimetry represents a substantial improvement over dosimetry obtained using CT imaging alone.

## Conclusions

Fusion of preoperative TRUS images with postimplant CT in this cohort has shown very good agreement with MR-derived dosimetry after permanent seed BT. Fusion of CT and TRUS may be a reasonable alternative in settings where MRI is not readily available.

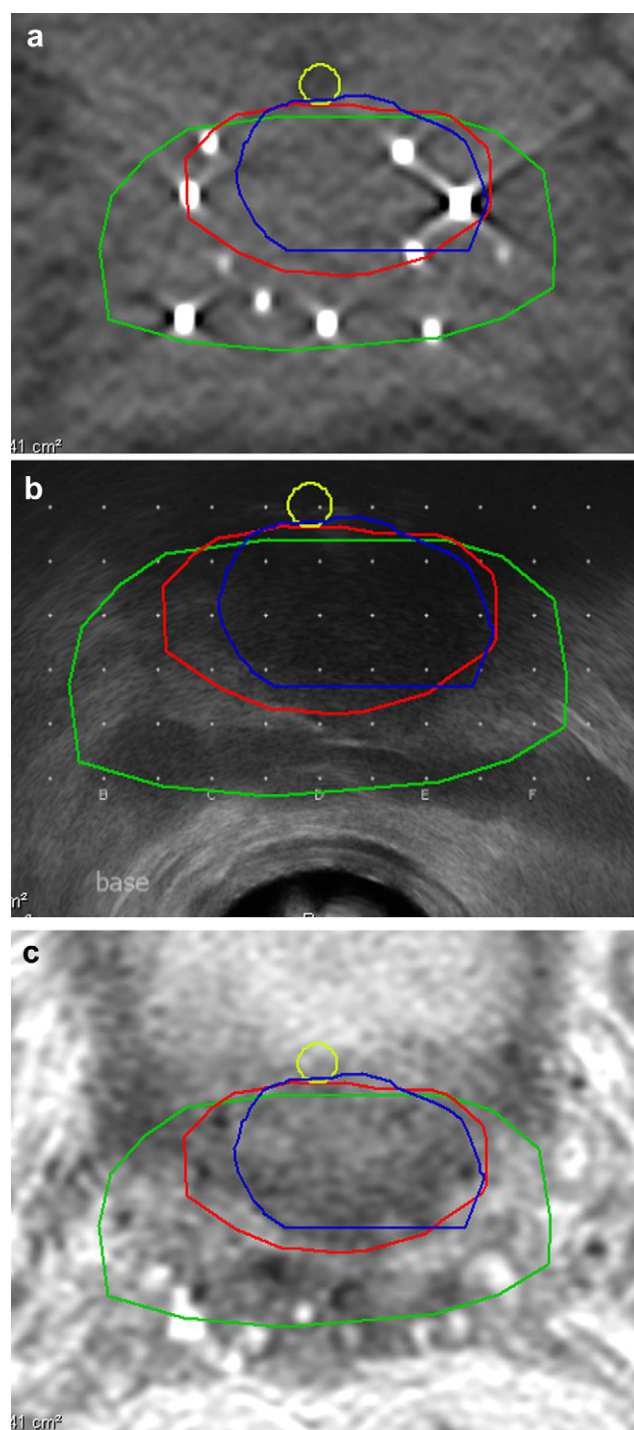


Fig. 6. Transverse images at the base showing prostate contours: transrectal ultrasound (TRUS, blue), MRI (red), CT (green). (a) TRUS image, (b) CT image, and (c) MR image. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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